Multibeam Sonar on an Autonomous Underwater Vehicle
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6 month progress report
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This document summarizes results to date concerning our efforts to integrate a multibeam sonar onto the Autonomous Benthic Explorer. We summarize computer and electronics development, dockside testing, on-vehicle testing, and results from our first deployment as part of the NOAA-sponsored Ring of Fire cruise to the Explorer Ridge

The pace of this effort was seriously compromised by scheduling. By the time of our award, we were nearly ready to depart on another NOAA OE field effort (Galapagos Rift). Between the Galapagos Rift cruise and the Explorer Ridge cruise, we had access to the vehicle for only 1 week in port in Seattle. Nevertheless we were successful in demonstrating the sonar over the most interesting terrain (Magic Mountain) studied on the cruise. We obtained excellent SM2000 data on 5 of 7 ABE dives, 4 of which were compete. These data contributed strongly to the success of the following leg of the Ring of Fire effort, where the ROV ROBPOS was used to perform close up survey and sampling on targets located by ABE.

The Autonomous Benthic Explorer, ABE

The Autonomous Benthic Explorer, ABE, performs fully autonomous surveys in the deep sea (figure 1) to depths to 5000 meters. It determines its position by using acoustic returns from a set of transponders moored to the seafloor. Based on information from these transponders, ABE descends to the seafloor to a precise location and then executes a series of preplanned tracklines. ABE surveys at preselected depths, or it can follow the bottom using returns from an acoustic ranging sonar [Yoerger 1998]. ABE carries a variety of scientific instruments including mapping sonars, electronic cameras, a magnetometer, and a variety of oceanographic sensors including, conductivity, temperature, depth (CTD), optical backscatter, and redox potential.

Multibeam Sonar

We selected to use the SM2000 multibeam sonar on ABE based on its previous success on the Jason ROV [Tivey and Johnson 2002]. The SM2000 operates at 200 khz and has a single fan-beam projector and an 80 element receive head., its electrical architecture allowed us to implement a controller and data logger suitable for an AUV

In conventional installation on an AUV, the SM2000 consists of three distinct subsystems. The first is the subsea unit, which consists of separate transmitter and receiver elements. The subsea electronics are a fully embedded, DSP-based system with high reliability. The second subsystem telemeters data to the surface at rates up to 10 Mbit/sec. The third subsystem is the topside unit, which performs a set of demanding real-time functions. The topside unit consists of an industrially-hardened PC running Windows with telemetry interface and a set of real-time digital signal processors. High-speed telemetry from the subsea unit provides raw element data to the surface. After the data is extracted from the telemetry stream, and the DSPs perform beam-forming and bottom detection. The Windows machine performs data logging and real-time display.

The manufacturer of the SM2000, Simrad-Mesotech, has built a version of the complete topside system that can be put in a subsea pressure housing. However, the size, weight, power consumption, and complexity of this approach are unattractive for the ABE application. The system draws nearly 100 watts, would add nearly 50 extra pounds of payload, and we found the prospect of dealing with Windows in an embedded, fully autonomous system unattractive.

Fortunately, we did not need most of the functions of the conventional topside processor in realtime, and for the AUV we could adopt a simpler approach. We recorded the raw element data, and performed all remaining steps in postprocessing. While this resulted in recording large amounts of data (~200 Mbytes/hours), the flow was manageable with inexpensive embedded computers and hard drives.

Simrad-Mesotech provides for a serial interface (rs422) that puts out raw element data at a speed of 460kbaud. This type and volume of data matches up well to the capability of PC104-based embedded computers running Linux that we have developed sucessfully for AUVs like SeaBed and ABE. The serial interface permitted the sonar to ping once every 2 seconds with sufficient sampling rate. We were supported by the manufacturer in this effort.

The realtime system capabilities were straightforward, since our goals were restricted to setting up the sonar and recording the serial ouptput. First, the realtime system sets up the SM2000 electronics, including sampling rates, ping rates, gain parameters, and initial range gate. Then the system logs the resulting returns with an appropriate time stamp. After recovering the vehicle, data was offloaded using a 100 Base T ethernet link.

The resulting data files were processed using a software package developed at APL/UW and WHOI implemented in Matlab. This package performed beamforming and bottom detection, and produced a set of range/angle pairs for each ping. These were then merged with position and attitude data using existing WHOI software (also implemented in Matlab).

Shallow Water Testing

We first implemented the controller on a conventional Windows PC using a USB serial interface and Borland C++ Builder. This proved to be a convenient development platform and allowed good technical progress to occur while we assembled the embedded PC104 computer with appropriate high speed serial interface. Using this setup, we were able to work out the proper sequence of commands, timing, interaction with data logging, etc. and logged pings in the test well on the WHOI dock.

When the embedded logger became available, we ported the code to the Linux environment. This was straightforward since the ANSI C code was directly compatible. A suitable serial library based on

ABE's infrastructure was used with minor modification.

Vehicle Integration

After considering all options, we decided to put the SM2000 control/logging electronics in a separate pressure housing mounted above the main housing (see figure 1). The limited time available between field deployments of ABE precluded a more elegant approach. The head and projector were mounted in the vehicle tail.

Vehicle operations

We tested the SM2000 installation on ABE on the Ring of Fire cruise to the Explorer Ridge on the University of Washington's Research Vessel Thomas G. Thompson. The co-chief scientists were Robert Embley and Edward Baker of the NOAA Pacific Marine Environmental Laboratory. We departed from Seattle, Washington after final integration and dockside testing on June 29, 2002, transitted to the Explorer Ridge site (49 45'N, 130, 16'W), and returned to Victoria, British Columbia on July 11. We would especially like to acknowledge the cooperation and support from both shoreside and marine personnel from the University of Washington.

ABE made 7 dives on the cruise, all of which returned the following science data:

1 vehicle position from long baseline acoustic navigation
2 vehicle attitude
3 vehicle depth
4 temperature
5 conductivity
6 redox potential
7 single beam echo sounder, 1 sec intervals
8 3-axis magnetometer
9 mechanically scanned sonar 2.5 pings/second

SM2000 data was returned from 5 of the 7 dives, 4 of which were complete covering 108 km of trackline. On the first dive, ABE73, SM2000 data logging stopped due to a program bug on the SM2000 data logger. When bad characters (caused by electrical noise?) were received on the data line between the main ABE computer and the logger, this caused the logging program to halt. While we attempted several fixes to this problem, the same problem occurred on ABE78 and ABE79. The inter-computer communication will be made more robust before our next cruise.

All data with the exception of the SM2000 was processed within a few hours after each dive.

All SM2000 data was processed over the course of the cruise. In the beginning, we had a lag of several days, but by the end of the cruise we could turn around the multibeam maps in less than 24 hours.

Conclusion

We successfully built an autonomous controller for the SM2000 sonar, tested it dockside, integrated onto our autonomous ABE vehicle, and participated in a 2-week cruise to the Explorer Ridge. We made a complete multibeam map of the Magic Mountain site and surrounding area, which was used successfully on a following cruise with the ROBPOS ROV.

In the next several months, we will be working on several follow up efforts. These include further postprocessing of the data set, presenting results at the December AGU meeting in San Francisco, and completing the integration of the SM2000 into ABE.

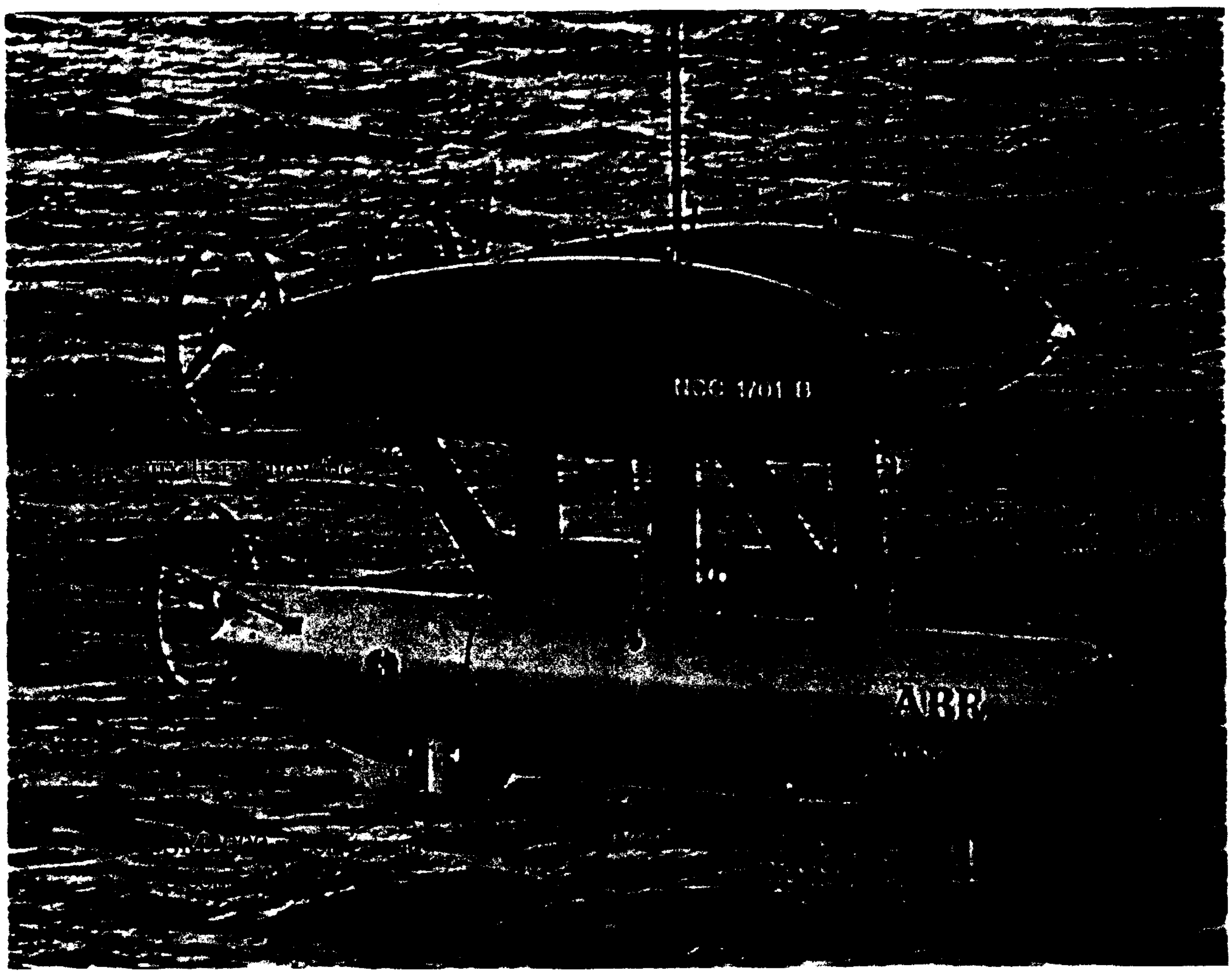

Figure 1, The Autonomous Benthic Explorer, ABE. ABE locates it position using long baseline acoustic transponders and follows preprogrammed tracklines while following the seafloor at a prescribed height. ABE routinely carries CTD sensors, 3 axis magnetometer, and a mechanically-scanned bathymetric sonar. Under this effort, we integrated an 80 element multibeam sonar, which increased the density of bathymetric soundings by a factor of 30

dive number	date	launch time	survey_start	survey_end	time on surface	time on deck	survey time	km surveyed	sm2000 km
abe73	01-Jul-02	17:01	18:47	30:03	31:41	32:18	11.27	24.76	0.00
abe74	02-Jul-02	20:35	22:06	31:01	32:35	33:27	8.92	19.13	19.13
abe75	03-Jul-02	20:40	22:20	31:05	32:38	34:32	8.75	18.07	18.07
abe76	05-Jul-02	03:27	05:08	18:52	20:27	21:06	13.72	29.41	29.41
abe77	06-Jul-02	11:42	13:14	28:12	29:51	30:22	14.97	32.86	32.86
abe78	07-Jul-02	21:35	23:05	36:56	38:37	38:59	13.85	28.63	0.00
abe79	09-Jul-02	03:12	04:45	18:14	19:53	20:18	13.48	28.41	9.00
						total time:	84.96		
						total km:		181.27	
						total sm2000 km			108.47

Table 1. Dive statistics for ABE on the Explorer Ridge cruise

Acknowledgements

We had many critical contributions to enable us to achieve these results on such a short schedule. We thank our collaborators at NOAA/PMEL Robert Embley, Edward Baker, and William Chadwick for the opportunity to take this system to sea, and their guidance in making sure we used our new tool to best advantage for their scientific goals. Marlene Messina handled contractual matters at WHOI. Edward Scheer, Keith von der Heydt, and Neil McPhee implemented the embedded logger and controller. Chris Jones of APL/UW provided critical advice in use of the SM2000, and Dezhang Chu provided the post-processing software. We gratefully acknowledge the support and cooperation of the crew of the RV Thomas G. Thompson and the UW Marine Dept. This effort was funded primarily by the NOAA Ocean Exploration program.

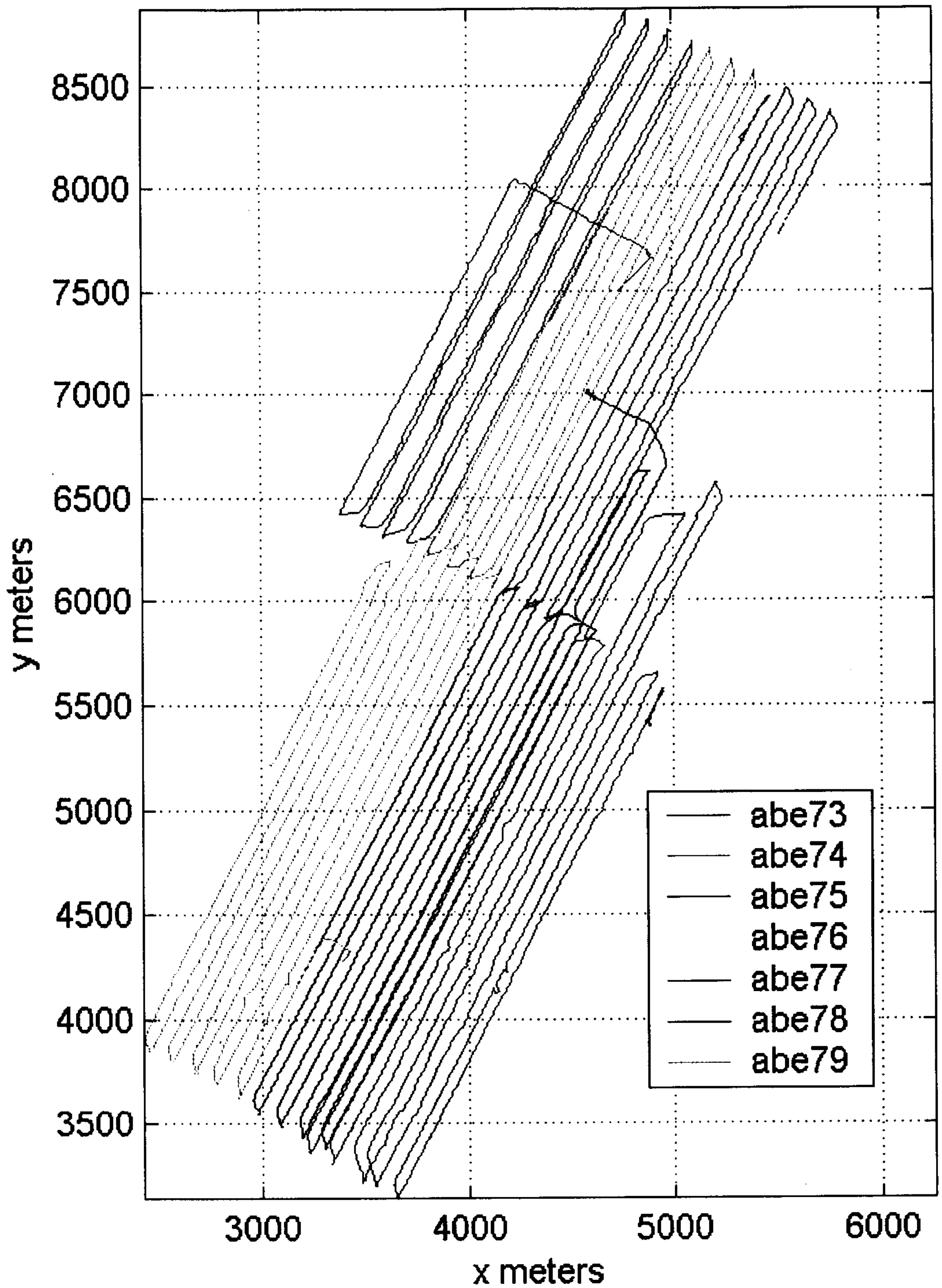

Figure 2. This plot shows ABE tracklines for all 7 dives. Dives 74-77 contained complete SM2000 records, and dive 79 had a partial record. These tracks covered 181 km over 85 hours of survey time.

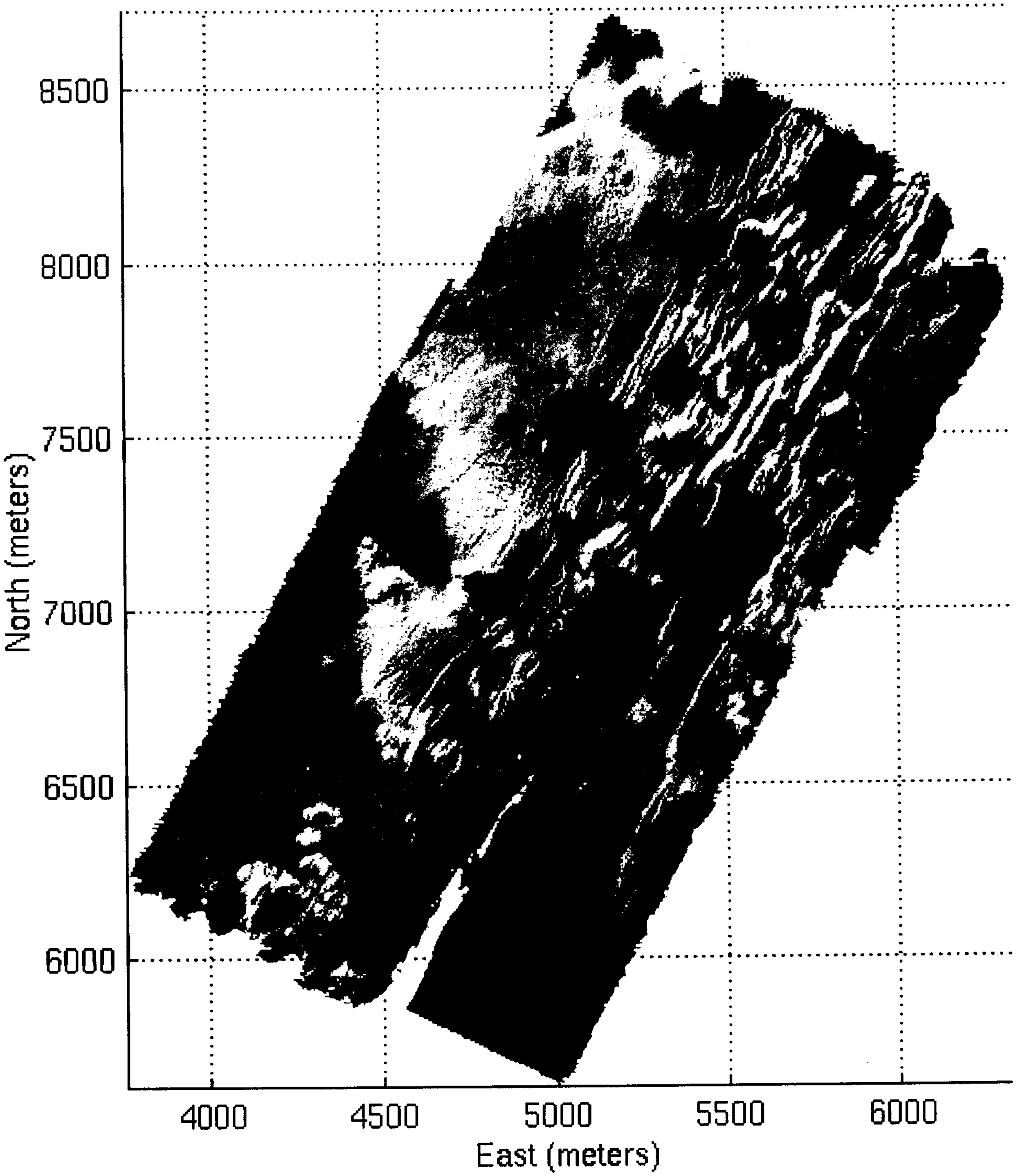

Figure 3. This plot shows results from the SM2000 for dives ABE 74, 75, and 76.

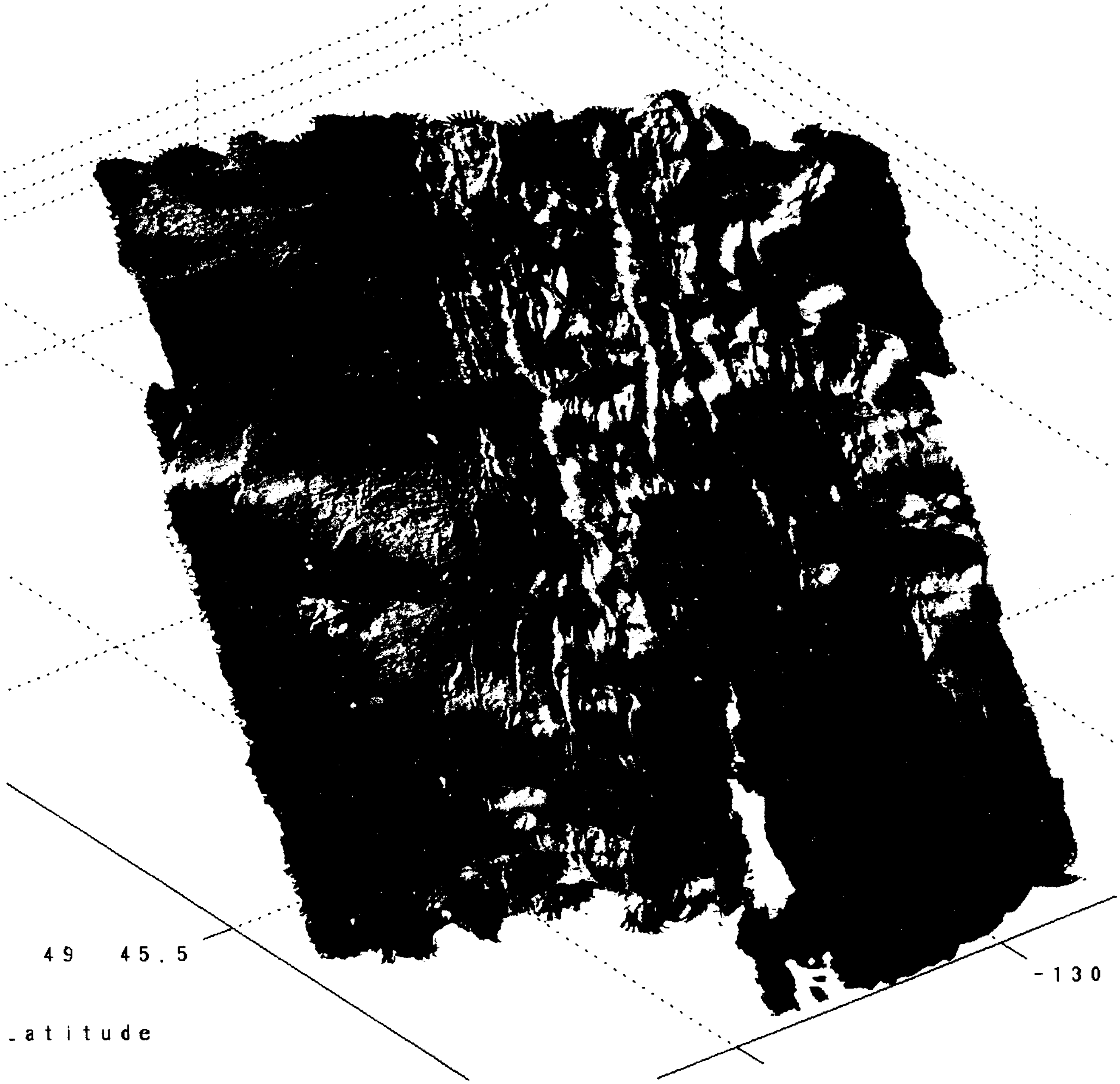

Figure 4. This plot show the same data as in figure 3, but from an oblique view

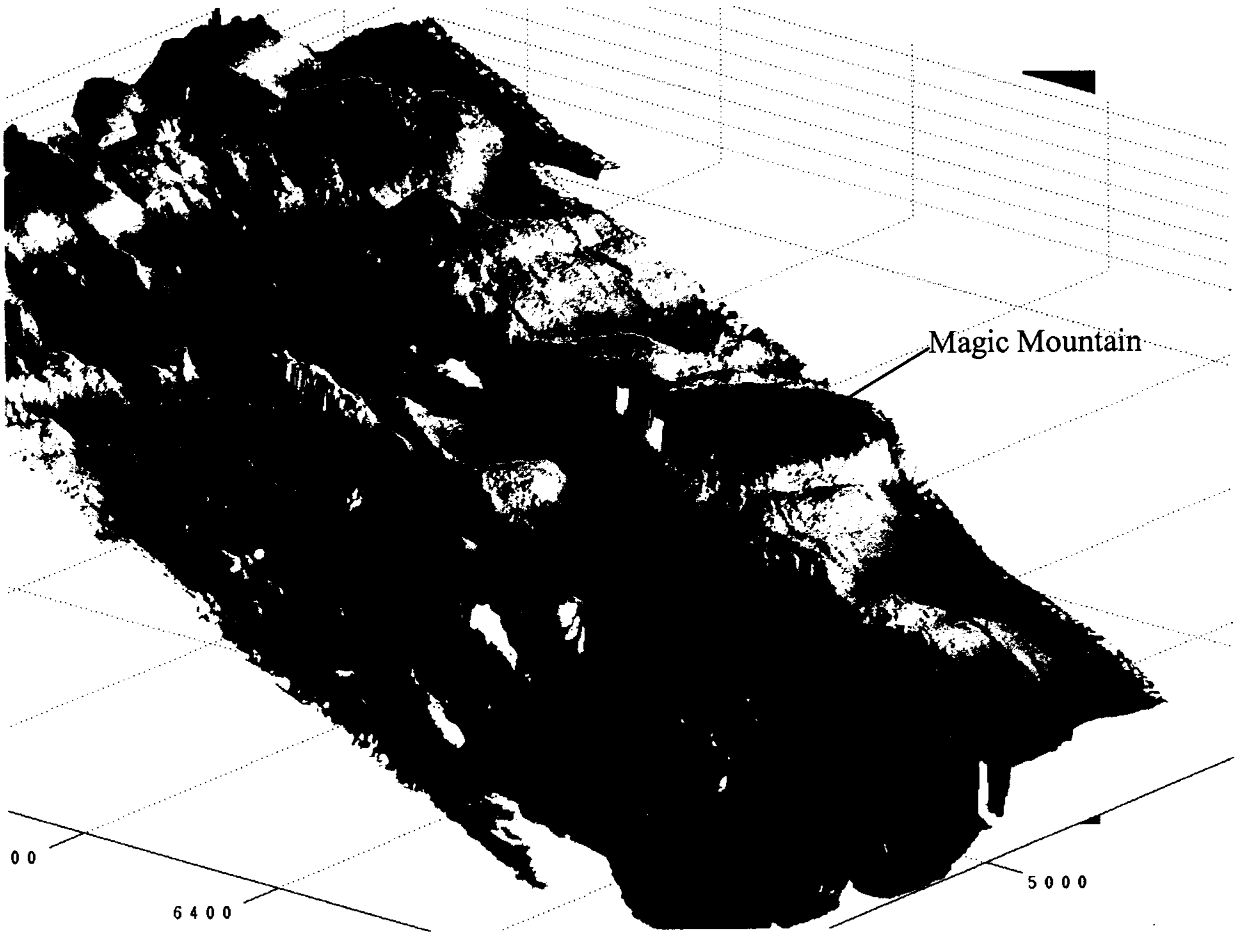

Figure 5. This plot shows the Magic Mountain site. This section of the data set was drawn from ~6 tracklines. The along-track features apparent in the valley are not artifacts, as they occur in overlapping tracks.